Earth System Research Laboratory
Global Systems Division

Assessing the Potential Impact of GPM Data Assimilated into Variational LAPS

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Introduction

- A brief explanation of variational LAPS
- The goals of this work
- Progress to date
- Future activities needed to reach our goals

Variational LAPS

- A 3|4DVar version of the older traditional LAPS (Local Analysis and Prediction System)
- Multivariate solution
- Solves on multi-scales working from coarse resolution to full scale
- Efficient
  - Interpolates from nearest grid points to ob location
  - Redefined every time the grid mesh expands to more points (higher density)
- Utilizes adjoints that can be applied to GSI
  - Adjoints speed up solution
  - Development of FM and adjoint code will be shared at-large

- For this reason (the adjoint consideration) we sought a specific type of forward model, i.e., it should be differentiable and tie into our control variables.

GOALS

- Assess the impact of satellite reflectivity data when used with ground-based data of similar type in its ability to create a superior analysis and forecast.

- Determine a suitable FM
- Define a roadmap

Forward models suitable for vLAPS testing

- Control variables rain, snow, graupel, cloud liquid, cloud ice, ambient temperature (hydrometeor type and stability).

- Start with dBZ measurements from Ku band
  - Similar to TRMM radar, but more sensitive
  - Generally Rayleigh scattering regime, though may need corrections for large hydrometeors
    - Use LAPS/WRF conversions from hydrometeors to dBZ

- Up-front attenuation corrections, based on Ku and Ka band data, as well as microwave imager

- Ka band can see smaller hydrometeors, though would be outside Rayleigh scattering regime for most precipitation (Ka band is between Ku band and radar on CloudSat)

- Use radar reflectivity values and ambient temperature to help constrain hydrometeor type

Investigated potential forward models:

- Kuligowski
- Bussinger (U of HI)
- Matsui GPM simulator – deemed too complex and potentially unfeasible with the funding level we have
- Models and methods shown at various GPM webinars

Most of the above were empirical (which may introduce adjoint issues) but also had uncertain (to us) tie-in to our control variables. We soon realized it would be easiest for us to apply our own, ground radar – FM for this study.

Decided on forward model:

- LAPS in-house system (developed by Steve Albers)
  - Requires either Cartesian or ground-based radar-centered coordinate system
  - Familiar with this system, know the control variables
  - Can test without adjoint, but know it will allow adjoint development

  For our case study (time not critical), we don't require an adjoint. For eventual routine operation (when that day comes after acceptance and funding) an adjoint will have to be devised and tested.

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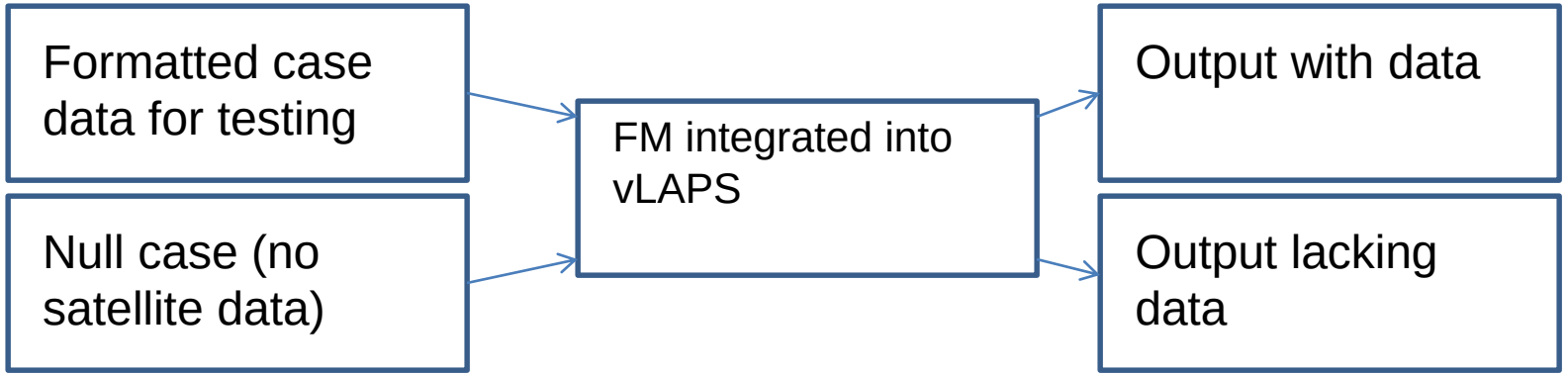
Year 1 objective – Identify case and code forward model

- All fast forward models (FM) investigated so far are empirical and may not lend themselves to our desired goal (needed adjoint).
- A strong relationship exists between the FM and operational data format
- Our current objective is to derive a FM from existing radar algorithms used in vLAPS and apply these to space-borne radar
- Two efforts shown below will be done in parallel then joined.

- These will then be integrated into vLAPS in the coming year testing with and without data as an initial impact study



PROGRESS

- Assess the impact of satellite reflectivity data when used with ground-based data of similar type in its ability to create a superior analysis and forecast.

- Determine a suitable FM
- Define a roadmap
- Identify a case that satisfies the research criteria
  - CONUS
  - Domain contains ground based radar data
  - Utilize TRMM dBZ data as a GPM proxy
  - Something unique about the polar data that might give it an advantage
    - Open water
    - Mountainous areas (Western US)

Deciding a case:

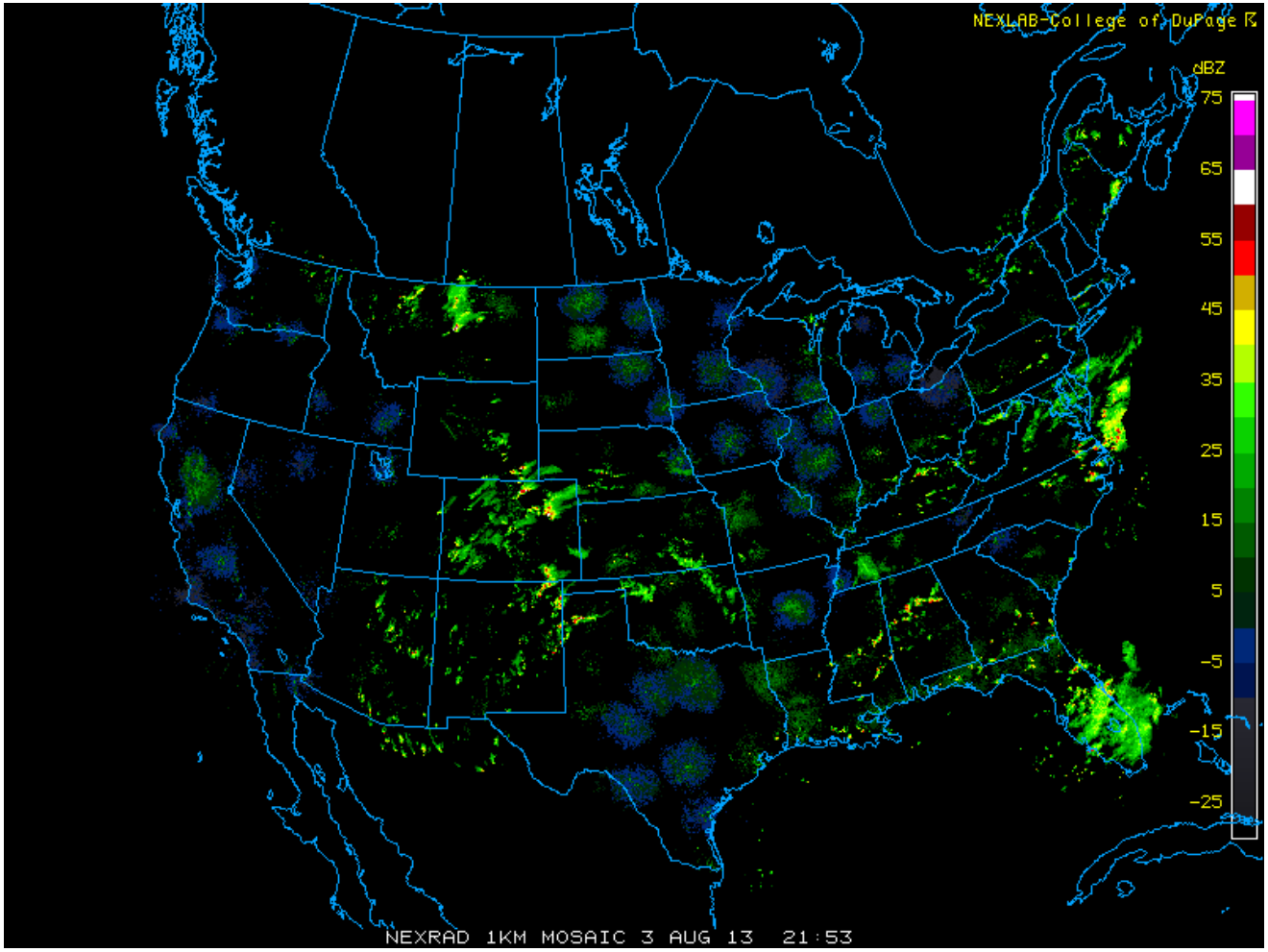
- Polar satellite radar case selection had no counterpart in prior LAPS work
  - We have worked some with cloud-sat data and sought a similar tool for identifying the ground track as a function of date and time for easy alignment with storms and active weather. Could not find such a tool.
  - Used a tool (**Thor 2.1**) to image TRMM 1C21 files for reflectivity track
    - Disadvantage of reading individual files to find a potential case.
    - Tedious to use since we had to download file by file to see if we had a potential match with a good case.
    - Identified two cases then selected one.
      - 3 Aug 2013
      - 26 July 2013
  - Discovered later that 1C21 is not the best dBZ data to work with, we need instead to focus on 2A25 as these are attenuation corrected.
  - Discovered later that a orbit tracking tool is available for TRMM radar data at: (courtesy of Bob Morris, NASA).
    http://cloudsgate2.larc.nasa.gov/cgi-bin/predict/predict.cgi

Deciding a case - 3 Aug:

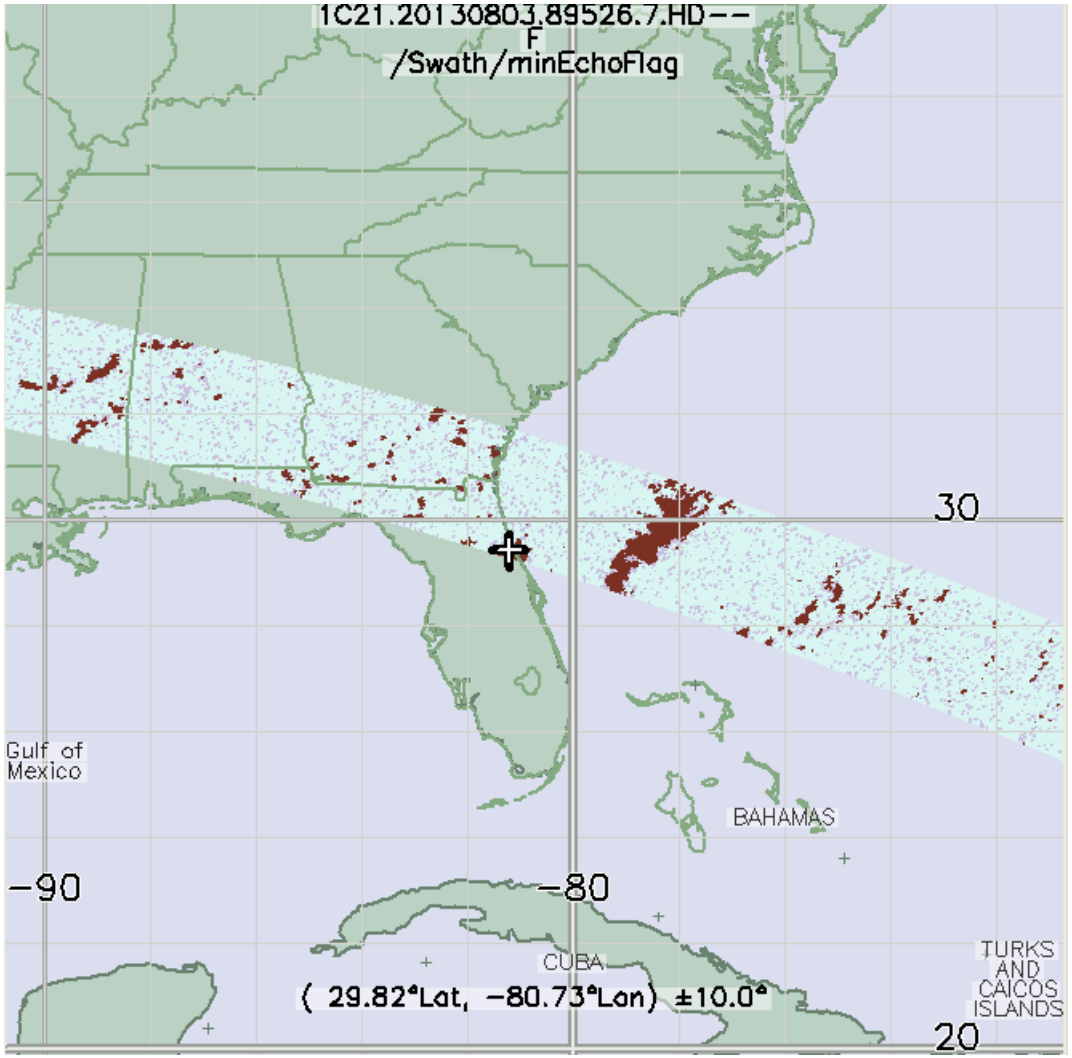
- Convection was in the area around FL but we had no idea about the satellite pass.
- Downloading the appropriate file and using Thor 2.1 we were able to image the pass with respect to neighboring convection

- Unfortunately as you can see, the result was not optimal so another candidate case was sought.

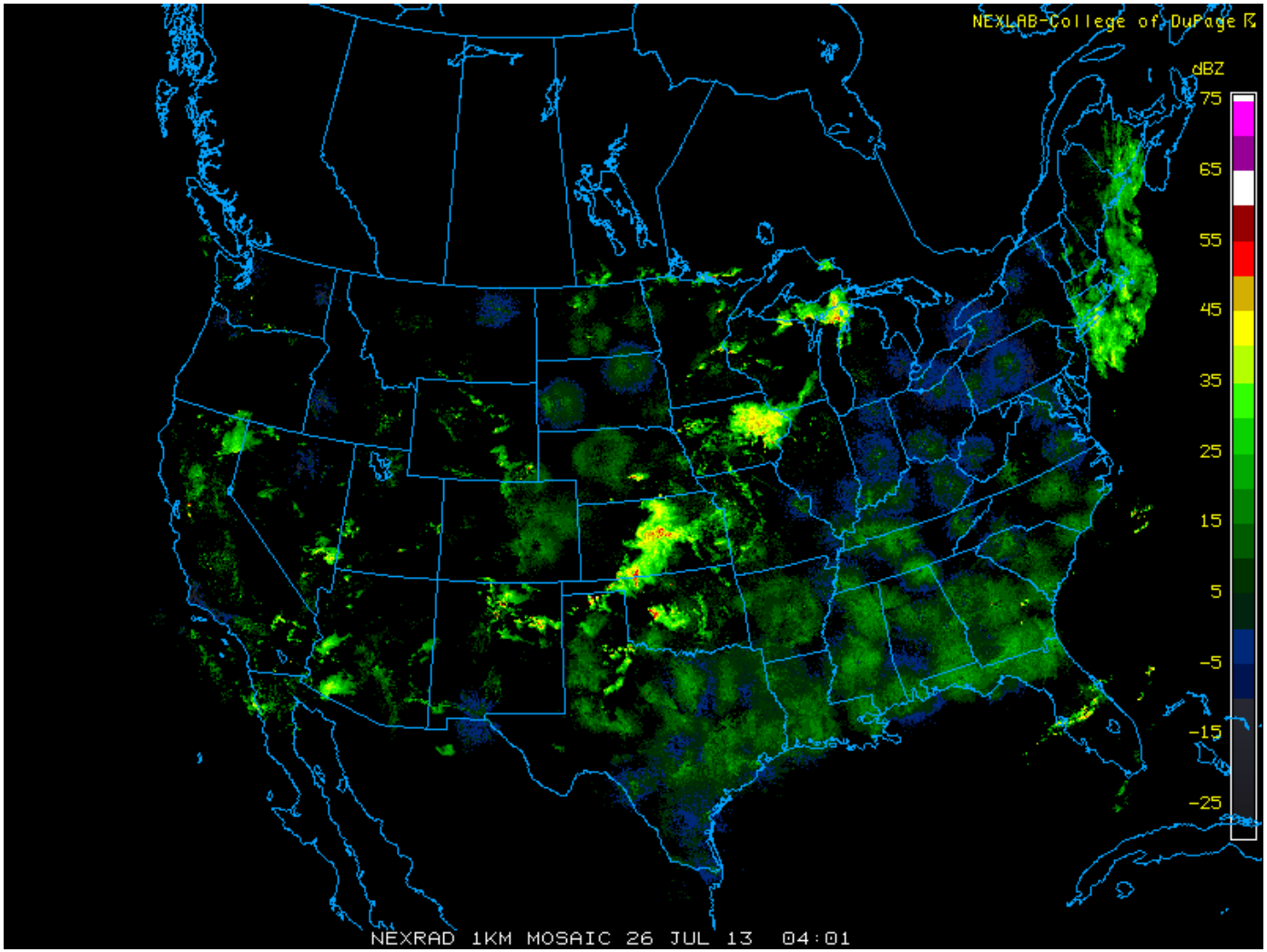
Deciding a case 3 Aug (Ground radar):



Deciding a case 3 Aug (TRMM radar):



Deciding a case 26 July: Ground Radar



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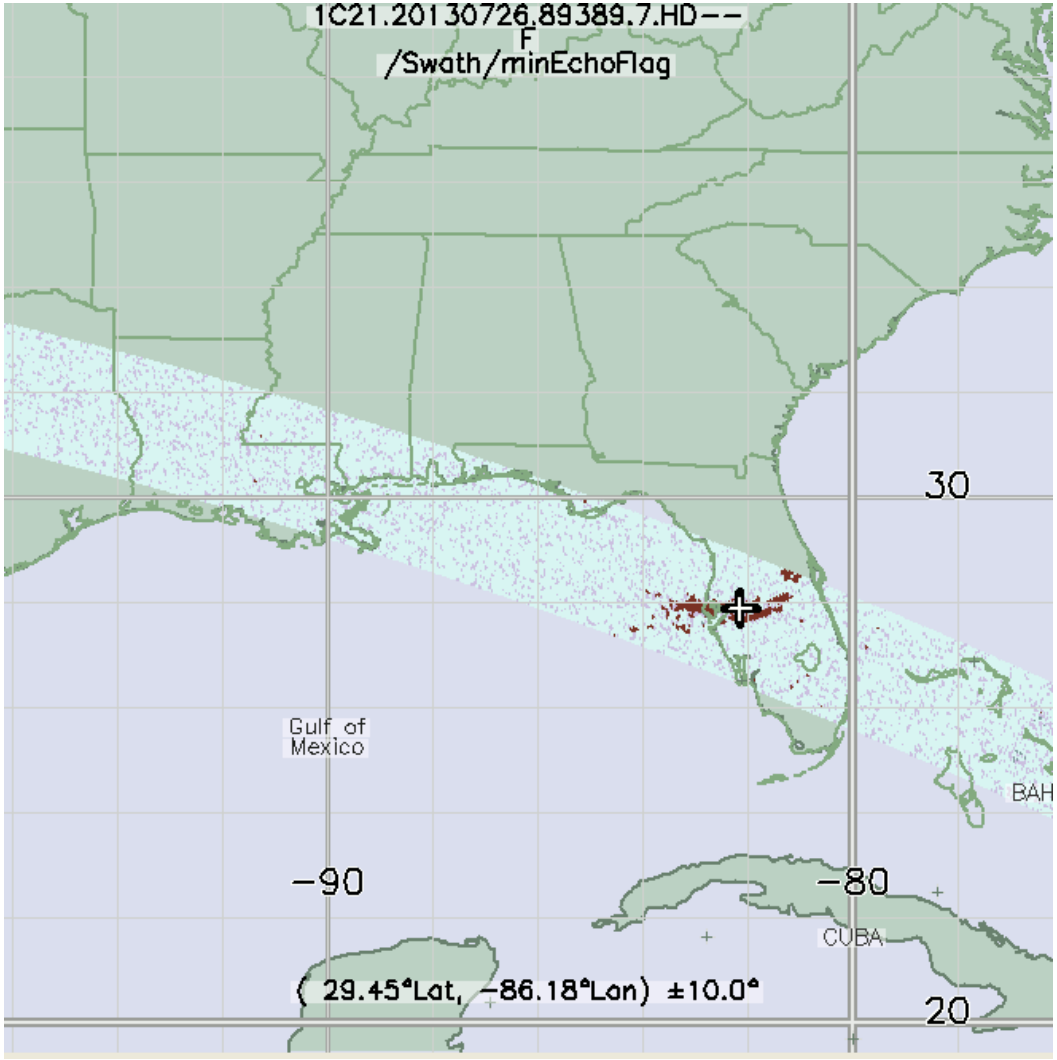

Decided on a case:

- Chose the July 26th case:
  - Captured full thunderstorm over FL.
  - Some of this is off-shore and may not be picked up that well by surface radar, but gives space-borne radar a chance to show its potential.
  - Plan to model the evolution of this storm both with and without TRMM data
  - Will evaluate result against ground-based radar data.

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  - CONUS
  - Domain contains ground based radar data
  - Utilize TRMM dBZ data as a GPM proxy
  - Something unique about the polar data that might give it an advantage
  - Develop a strategy to get the satellite data into our coordinate system for utilization
    - Working with Bob Morris at NASA
      - Obtained IDL software last week (22nd) to perform the transform
      - Place satellite data into the ground radar Cartesian grid that our current ingest can handle.

Current activity – remapping to Cartesian system to merge with vLAPS assimilation:

- Downloaded the 2A25 data for the case
  2A25.20130726.89389.7.HDF
- Working with Bob Morris on tools to do the coordinate transform of the data to Cartesian.
  - Bob has provided us with IDL code to perform this transform
    - If we decide this is a feasible way to do this for "production" we will be working with this code to possibly integrate it into our system
    - Potentially rewriting it to some other language than IDL for routine processing
  - For the purposes of this case, either we will run the IDL software or Bob may graciously do this for us.

Plans:

- Remap the TRMM data into ground-based Cartesian grids
- Read in the satellite data in this format into our analysis system
  - Code exists – essentially waiting for the data
- Run the two experiments
- Validate each set of reflectivity forecasts with ground-truth observed radar
- Evaluate results – make decisions as to next step

- Upcoming work:
  - Construct adjoint for our FM
  - Look hard at the strategy for regridding the data.
    - Is this the best way to do it for GPM, other users?
  - Integrate system to vLAPS
  - Assimilate GPM data when code and data availability permits.

Summary (near term) (future):

- Most of the major leg work has been done
  - We now have a pathway to insert space-radar data into an analysis system
  - We have identified a viable case
  - Data for that case is being transformed to a grid we can assimilate
  - Once these data are interfaced to the FM we can make our runs
- Future work
  - Assess the forecast model output (forecast radar reflectivity)
  - Use observed radar to assess position and intensity
  - Consider a mountain-region case, or another case where we have poor ground radar coverage over an area of interest to compliment this case.
  - Publish these results
  - Better optimize the means to get the satellite data into the FM framework for GPM
  - Create an adjoint if we are satisfied with the results
  - Share the GPM FM and adjoint with user community
  - Implement the system into vLAPS full time.